The Guidebook to Molar Endodontics

Ove A. Peters
Editor

Springer

The Guidebook to Molar Endodontics

Ove A. Peters
Editor

The Guidebook to Molar Endodontics

Springer

Editor
Ove A. Peters
Department of Endodontics
University of the Pacific Arthur A. Dugoni School of Dentistry
San Francisco
California
USA

ISBN 978-3-662-52899-0 ISBN 978-3-662-52901-0 (eBook)
DOI 10.1007/978-3-662-52901-0

Library of Congress Control Number: 2016958572

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer-Verlag GmbH Berlin Heidelberg

Preface

Dear reader:

You may think, “Why another textbook on endodontics?” and you are absolutely right to ask that question. The purpose of this book is in my view a bit different from a typical textbook, and hopefully this becomes apparent when you read it.

Historically, the intention of a guidebook, according to several dictionaries that I consulted, was to give information to travelers. Regardless of whether you are a seasoned clinician or a beginner, you may want to travel deeper into molar endodontics, and this book intends to give you support in your decision-making and execution of the treatment plan.

The idea for this book was born out of several pertinent findings in discussions with endodontists, residents, general dentists, and fellow faculty members:

- Do we teach molar endodontics sufficiently to dental students or should they take additional training to perform this procedure?
- Are modern technological developments, such as the use of the operating microscope or cone beam computed tomography (CBCT), essential to successful molar endodontics?
- Is avoiding a gross mistake as important as doing the little things right in achieving success?

The latter question came to the forefront when I considered the use of checklists for clinical procedures [1]. While it would be dangerous to oversimplify endodontics, it surely helps to step back occasionally and make sure that the right thing is done. Better yet, one would like to use clinical evidence whenever available to support the course of action.

This is the reason that each chapter in this book has a number of references but also one key citation that can help to directly address a clinical quandary. With this comes the need to reevaluate the standard of practice periodically to include new and pertinent information.

This task would be insurmountable if it were not for my coauthors who were each responsible for a chapter in this book; I cannot thank each of them enough. From a clinical standpoint, there are several key principles that can be cited for procedural success in root canal therapy. The term “procedural success” is in my view related to what the clinician can do to promote best patient-related outcomes.

It is my impression that outcomes in endodontics are discussed more and more in a broader sense beyond the treatment of apical periodontitis; this is helpful so that we are not primarily focusing on radiographically confirmed resolution of apical bone defects but considering other outcomes that are relevant for our patients [2].

At a time where CBCT permits real-time imaging of apical conditions, without clearly defining what a normal periradicular space looks like, an assessment of our strategies is in order. I happen to believe the next step in this diagnostic paradigm will be molecular tests for pulpal and periapical conditions.

Obviously, the practice of dentistry varies from country to country, continent to continent, perhaps based on fee schedules and educational systems. This prompted me to solicit the help of well-educated clinician-researchers with diverse backgrounds for each of the central issues discussed in this book, ranging from molar anatomy over diagnosis and clinical treatment to outcome assessment, retreatment, and surgery.

It is my hope that you will enjoy the text as much as the supporting material in bullet points and images and, ultimately, go on to travel the road to successful molar endodontics.

San Francisco, CA, USA Ove A. Peters, DMD, MS, PhD

References

1. Gawande A. The checklist manifesto: how to get things right. New York: Metropolitan Books; 2009.
2. Azarpazhooh A, Dao T, Ungar WJ, Da Costa J, Figueiredo R, Krahn M, Friedman S. Patients' values related to treatment options for teeth with apical periodontitis. J Endod. 2016;42:365–70.

Acknowledgments

At this point, I must thank all involved in my career for their interest and enthusiasm for root canal treatment and all other aspects of endodontology; specifically, I am grateful for the guidance and support from my mentors Dr. Fred Barbakow, Dr. Harold Goodis, and Dr. Alan Gluskin.

I am greatly indebted to my coauthors and editors—their invaluable contributions made this book possible.

Most importantly, I would like to express my gratitude to my parents who started me in life with their attitude of hard work, curiosity, and support for whatever new project I came up with. Last but not least, my thanks go to my wife Christine. She is not only an educator and endodontist in her own right but also my favorite line editor; this book would not have been possible without her understanding and practical help.

Contents

Contributors

Ana Arias, DDS, MS, PhD Conservative Dentistry, School of Dentistry, Complutense University, Madrid, Spain

Elio Berutti, MD, DDS Department of Endodontics, University of Turin, Turin, Italy

Lars Bjørndal, PhD Section of Cariology and Endodontics, Department of Odontology, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark

Arnaldo Castellucci, MD, DDS University of Naples Federico II, Naples, Italy, University of Cagliari, Cagliari, Italy

Private Practice, Florence, Italy

Chloé M.F. Hardy, DDS School of Dentistry, Cliniques Universitaires Saint Luc – Université catholique de Louvain, Brussels, Belgium

Thomas Kvist, PhD, DDS Department of Endodontology, Institute of Odontology, The Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

Gaetane Leloup, DDS, PhD School of Dentistry, Cliniques Universitaires Saint Luc – Université catholique de Louvain, Brussels, Belgium

Julian G. Leprince, DDS, PhD School of Dentistry, Cliniques Universitaires Saint Luc – Université catholique de Louvain, Brussels, Belgium

Enrique M. Merino, MD, DDS European University, Madrid, Spain, Complutense University, Madrid, Spain

Private Practice, Leon, Spain

John M. Nusstein, DDS, MS Division of Endodontics, The Ohio State University College of Dentistry, Columbus, OH, USA

Frank Paqué, DMD, MSc Department of Preventive Dentistry, Periodontology and Cariology, University of Zurich Center for Dental Medicine, Zurich, Switzerland

Private Practice, Zurich, Switzerland

Ove A. Peters, DMD, MS, PhD Department of Endodontics, University of the Pacific, Arthur A. Dugoni School of Dentistry, San Francisco, CA, USA

John D. Regan, BDentSc, MA, MSc, MS, FICD Department of Endodontics, Texas A&M, University Baylor College of Dentistry, Dallas, TX, USA

North Texas Endodontic Associates, Plano, TX, USA

Frank C. Setzer, DMD, PhD, MS Department of Endodontics, Penn Dental Medicine, Philadelphia, PA, USA

Helmut Walsch, DMD, PhD, MS Department of Endodontics, Penn Dental Medicine, Philadelphia, PA, USA

Private Practice, Munich, Germany

David E. Witherspoon, BDSc, MS, MFA, FICD Department of Endodontics, Texas A&M University Baylor College of Dentistry, Dallas, TX, USA

North Texas Endodontic Associates, Plano, TX, USA

Molar Root Canal Anatomy

1

Frank Paqué

Abstract

Detailed understanding of root and root canal anatomy is the main prerequisite for successful molar endodontics. Besides typical three-rooted and two-rooted configurations for maxillary and mandibular teeth, respectively, there are specific variations such as merged roots, additional roots, and completely different shapes such as the C-shaped molars. Adding complexity, frequently small accessory canals are found that can contribute to periapical pathosis.

Guiding Reference

Stropko JJ. Canal morphology of maxillary molars: clinical observations of canal configurations. J Endod. 1999;25:446–50.

This clinical study on first and second maxillary molars treated over an 8-year period was made in an attempt to determine the percentage of second mesiobuccal (MB2) canals that could be located routinely. 1732 maxillary molars were treated and overall, the MB2 canal was found in about 73 % first molars, 51 % second molars, and 20.0 % third molars. It occurred as a separate canal in about 55 % of first molars, 45.646 % of second molars, and joined in all third molars. However, as the operator became more experienced, scheduled sufficient clinical time, routinely employed the dental operating microscope, and used specific instruments adapted for microendodontics, MB2 canals were located in about 93 % of first molars and 60 % in second molars.

F. Paqué, DMD, MSc
Department of Preventive Dentistry, Periodontology and Cariology, University of Zurich Center for Dental Medicine, Zurich, Switzerland

Private Practice, Rennweg 58, 8001 Zurich, Switzerland
e-mail: frank.paque@zzm.uzh.ch

O.A. Peters (ed.), *The Guidebook to Molar Endodontics*,
DOI 10.1007/978-3-662-52901-0_1

1.1 Introduction

A central goal of cleaning and shaping procedures in endodontics is to obtain a debrided root canal system that is in its entirety free of microbiota and debris. Therefore, detailed knowledge about root canal anatomy prior to any access to the root canal system is absolutely mandatory [1]. Moreover, complex root canal anatomy in molar roots should be expected in every single case. Root and root canal anatomy directly impacts practice and procedures for access cavity preparation, canal shaping and obturation, and in fact most procedures in molar endodontics (see Chaps. 5, 6, 7, 9, and 10 in this book).

It is well established that intraradicular microflora is the main cause for developing, or persisting, apical periodontitis [2]. Unfortunately, the intraradicular infection mainly consists not of planktonic bacteria but of well-organized biofilms. The bacteria in biofilms show a higher pathogenicity compared to their planktonic counterparts [3]. More than 400 different bacterial species were found in root canal systems of teeth with necrotic pulps [4]. Interactions between different species within endodontic biofilms lead to enhanced stress resistance [5]. Their location within complex molar root canal configurations makes complete eradication of endodontic biofilms virtually impossible; even reducing the microbial burden below a biologically acceptable threshold demands careful canal debridement. It is safe to say that in depth understanding of root canal anatomy is of upmost importance for successful molar endodontics.

1.2 Components of the Root Canal System and Classifications

In roots with round cross-sectional shapes, the number of root canals corresponds in most cases to the number of roots. However, an oval shaped root may have more than one canal [1]. The immense complexity of molar canal configurations is based on a wide range of root canal curvatures, different root canal sections, different accessory canals, fins, and isthmuses. Different attempts of classification contributed to a deeper understanding of root canal anatomy. There are numerous classifications for anatomical variations in root canals. Weine and coworkers [6] examined in a laboratory study the mesiobuccal roots of maxillary molars and classified these into four and later into five types as shown in Fig. 1.1.

A more detailed classification is recommended to more accurately describing the internal root canal configurations of individual molar roots. One of the most commonly used classifications is the one by Vertucci [7] with eight different canal morphologies (Fig. 1.2a).

However, if there are more than two canals within one root, this classification again is limited. Gulabivala et al. [8] further developed this classification to additional nine morphology types. Especially for describing the root canal formation of the mesial root in mandibular molars types 1, 2, and 3 of this classification is meaningful (Fig. 1.2b).

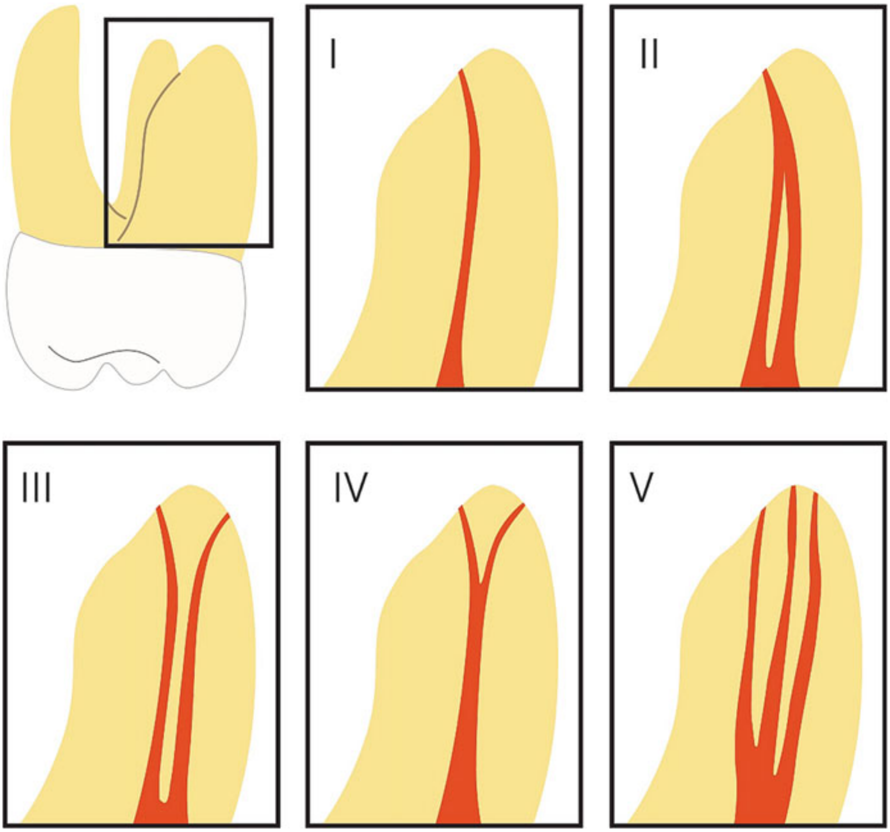


Fig. 1.1 Classification of multiple canals in one root by Weine et al. [6]. The original classification of four types was later expanded to the five configurations shown

Another research group [9] extended Vertucci's classification with additional 14 configurations examining 2800 extracted human teeth. These further developments contribute to the understanding of substantial complexity in root canal configuration.

1.3 Complexity of Root Canal Systems

As Vertucci [1] stated, a root with a tapering canal and a single foramen is the exception rather than the rule. Great complexity of root canal anatomy can be found at every level of the root canal space. It is the result of tooth development mainly after eruption of the tooth to the oral cavity and apical closing [10] due to the apposition of secondary dentin. The primary apposition of root dentin has determined the external shape of the root, and therefore the internal shape will be the very similar: if the external shape is round, the canal will also be round; if the external shape is long oval or kidney shaped, the canal will be long oval or kidney shaped too.

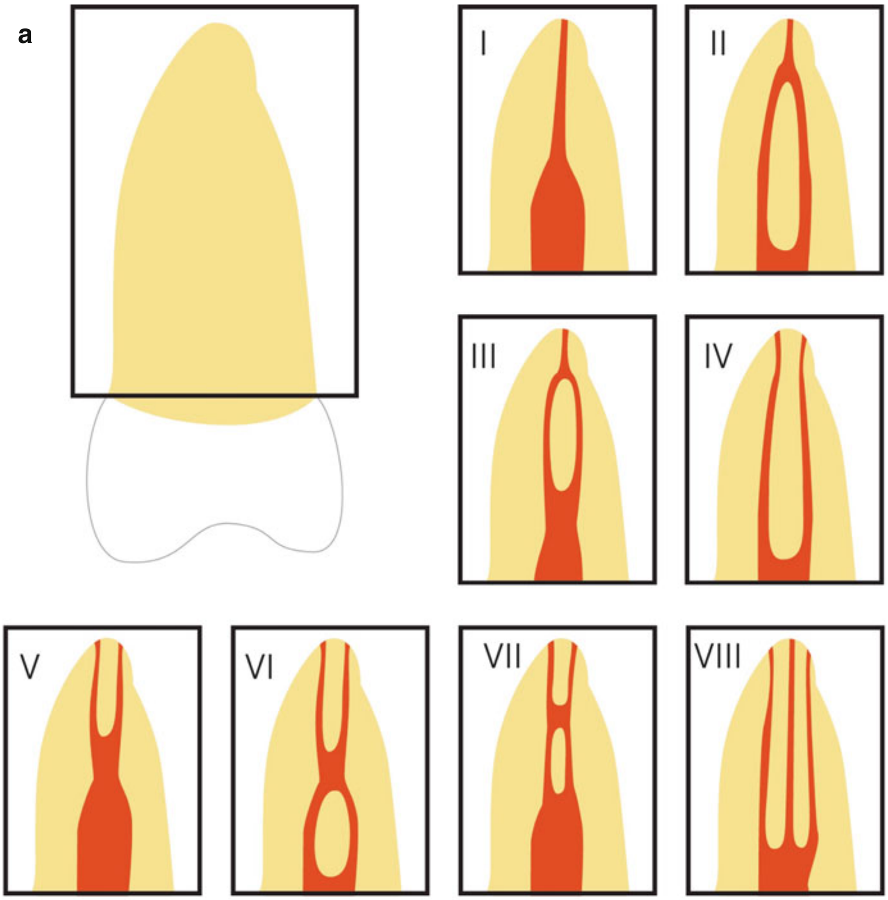


Fig. 1.2 Expanded root canal classifications by Vertucci [7] (eight types) (**a**) and by Gulabivala et al. [8] (seven types) (**b**)

Kidney-shaped roots, like in mandibular molars, mainly develop two root canals (Fig. 1.3).

For example, in mandibular first and second molars the root canal systems were completely defined at 30–40 years of age [10]. Various intercanal communications can still remain and represent one main component of complex root canal anatomy (Fig. 1.3). Others are wide ranges of root canal curvatures, different root canal cross sections, accessory canals, secondary canals, lateral canals, furcation canals, fins and multiple apical foramina, and so-called apical deltas.

More than two decades ago when rotary Nickel-Titanium instruments were introduced to the endodontic market, root canal curvatures have been stated as one of the most common endodontic complexity [11]. With the further development of these instruments and the experience gained by the practitioners, the difficulties of shaping even severely curved root canals have mainly been overcome over the past

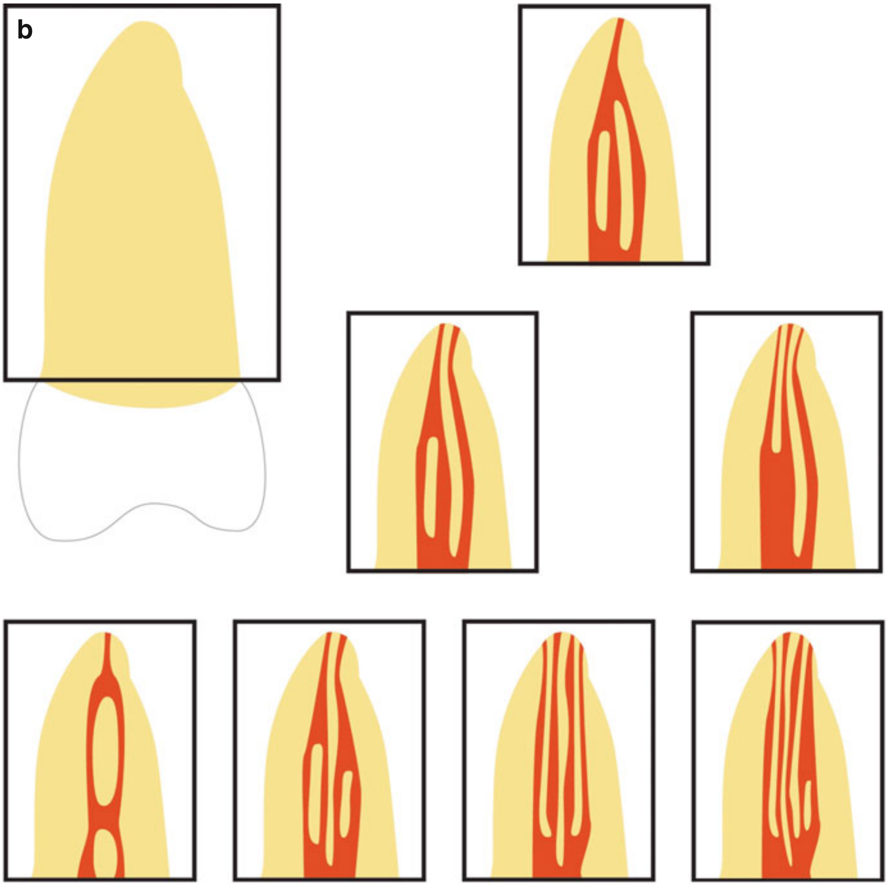


Fig. 1.2 (continued)

few years (Fig. 1.4). Taking into consideration that complex root canal systems require proper cleaning and disinfection, the main challenge remains to debride the spaces of the root canal system that cannot be reached by mechanical instrumentation. Especially in mandibular and maxillary molars, the above-mentioned components of complex root canal anatomy are a common finding. In a literature review about tooth survival after nonsurgical root canal treatments [12], the tooth type or specifically nonmolar teeth were found to significantly increase tooth survival.

1.4 The Anatomy of Maxillary Molars

A sufficient root canal treatment in maxillary molars is based on an optimal access to and preparation of all existing root canals. The goal of the treatment is to present the existing anatomy as comprehensive as possible and to widen the root canal system to

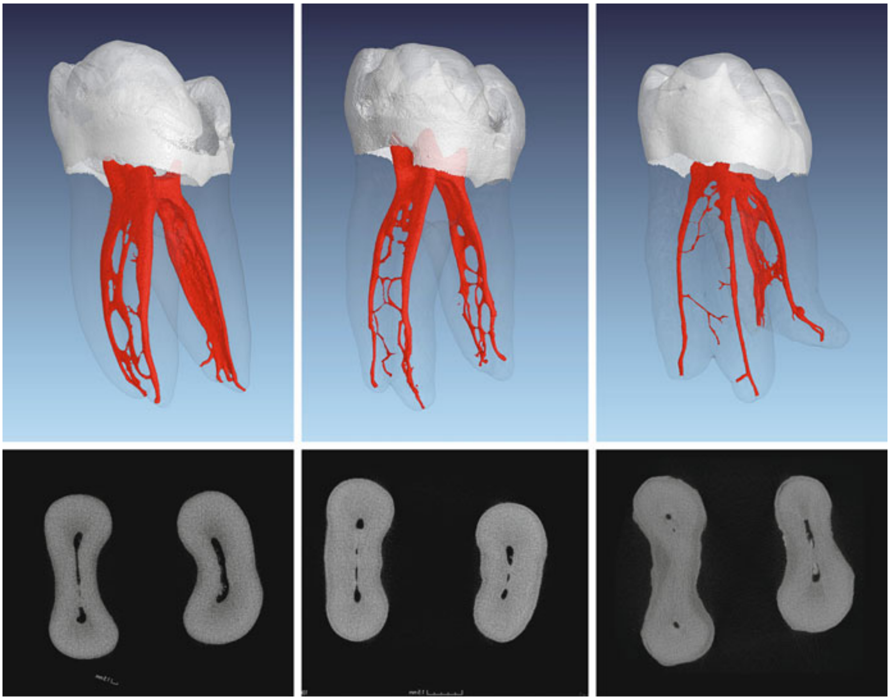


Fig. 1.3 Micro-computed tomography images of extracted teeth from patients of different ages. Three-dimensional reconstructions and corresponding cross sections from the middle third of the roots are shown. Images from *left* to *right*: extracted tooth of a young-aged, middle-aged, and older patient, respectively. Note the width of the main canals and the number and size of various ramifications and communications

enable a sufficient disinfection and filling. The anatomy of maxillary molars is very complex and the root canal treatment of this particular group of teeth represents a major challenge for dentists [1]. Carabelli documented the particular anatomy of maxillary molars as early as 1844 [13]. Numerous subsequent publications discussed the complexity of maxillary molar anatomy; most often the mesiobuccal root and the occurrence of a second mesiobuccal (MB2) canal have been in the main focus. In 1917, Walter Hess [14] presented the anatomical complexities with multitude of branches and accessory canals by illustrating in detail the number and formation of root canals. He was the first to relate age and gender of the patients to root canal complexity.

Many studies have shown the anatomy of the upper first molar and especially the presence of a MB2 canal using different techniques [15]. Failures in root canal treatment of this tooth type are often based on untreated MB2 canals [6, 16]. The clinical prevalence of the MB2 canal in maxillary first molars and in second molars is reported up to 93 % and 60 %, respectively [17].

Results from laboratory micro-computed tomography (micro-CT) studies are of special interest for molar anatomy, because this technique allows a three-dimensional presentation and analysis of the root canal system without damaging the tooth

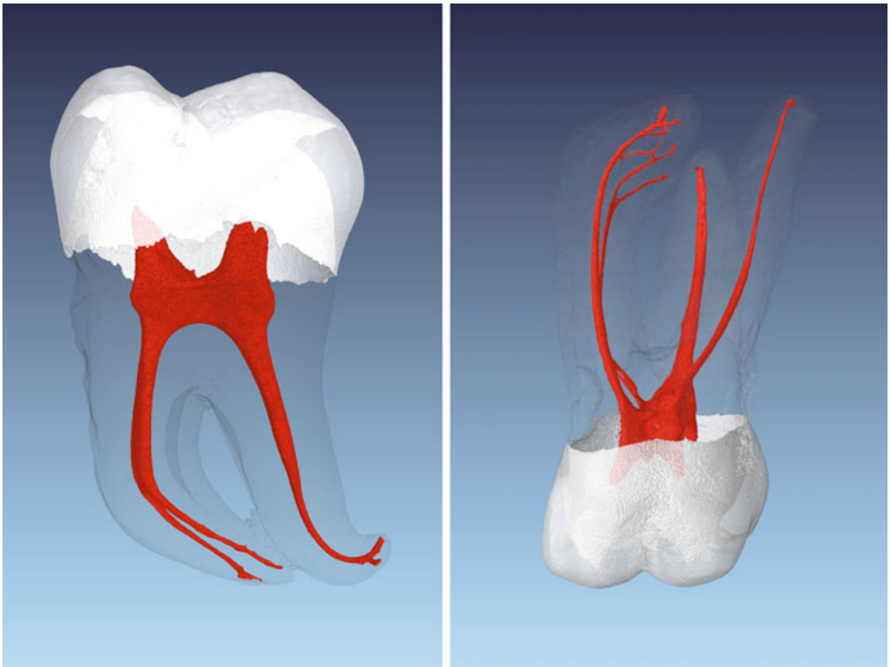


Fig. 1.4 Micro-computed tomography images of an extracted mandibular and a maxillary molar. Note the severe canal curvatures in both roots of the mandibular molar and in the MB root of the maxillary molar

structures [18]. Due to modern treatment methods like the use of dental microscopes, options for a successful therapy of difficult root canal anatomies have significantly improved [19]. The location of MB2 canals during root canal treatment of maxillary molars is much more likely by applying the dental microscope and through the use of specialized tools than without [17].

The first maxillary molar is the most voluminous of all teeth: it has four pulp horns and the pulp chamber has usually a rhomboid cross-sectional shape [1]. The second maxillary molar in principle is of similar shape (Fig. 1.5a). However, the pulp chamber is often more long oval, sometimes it is ribbon shaped (Fig. 1.5b).

A maxillary first molar has typically three separate roots and in only about 4 % of the cases just two roots are found. Two or more merged roots occur in about 5 % of all cases. The presence of four roots is extremely rare [15]. In second maxillary molars, merging of roots is much more common. Interestingly, the distobuccal (DB) root canal in second maxillary molars is often difficult to negotiate because an S-shaped DB root is a quite common finding.

Cleghorn et al. [15] evaluated laboratory studies from the years 1914 to 2004 in a literature review of the anatomy of the first maxillary molar. The occurrence of a MB2 was reported to range from 25 to 96 %. Pooled data of 21 studies gave an overall prevalence of roughly 60 %.

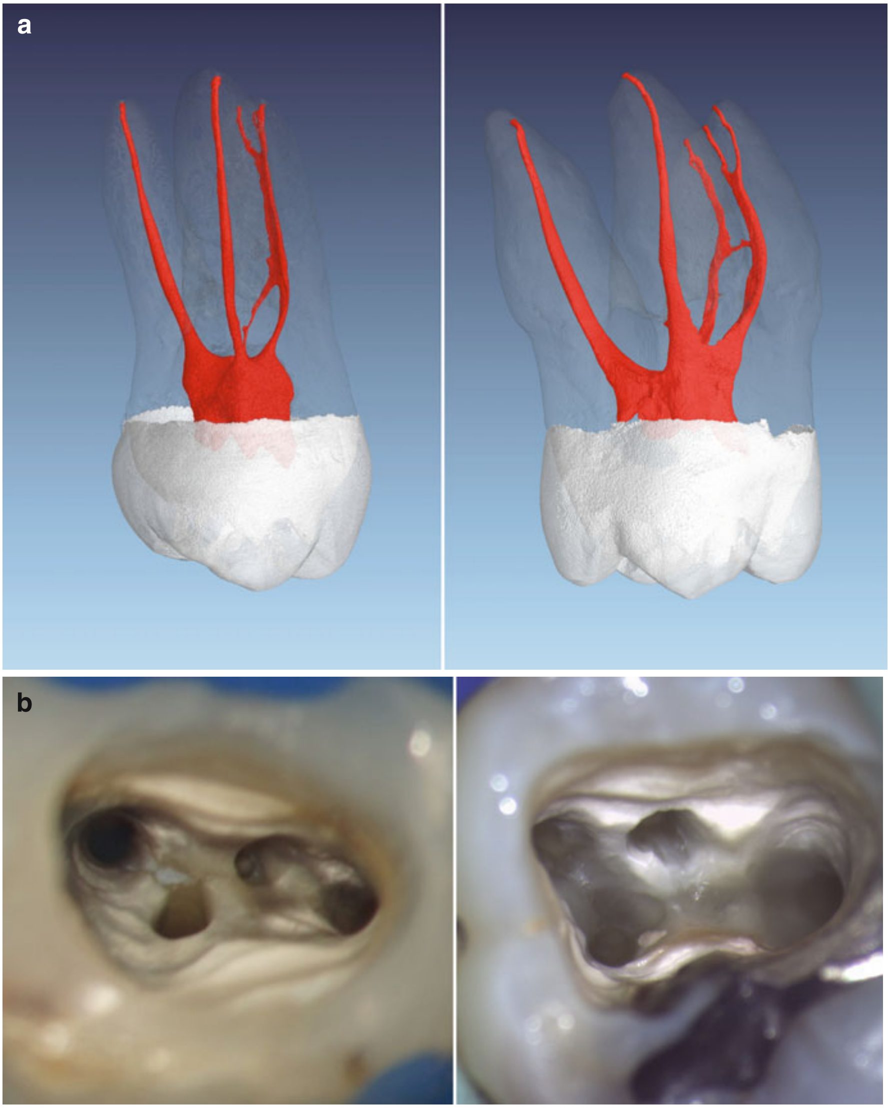


Fig. 1.5 (**a**) Micro-computed tomography images of an extracted first (*right*) and second maxillary molar (*left*). Note the in general similar shape but the overall smaller volume of the second maxillary molar. Typically, the buccal roots of the second maxillary molar seem to be fused. (**b**) Clinical images of cases after preparation of all canals in a first (*right*) and second (*left*) maxillary molar with rotary instruments. The access cavities provide an overview of all four canal orifices. Note the ribbon-shaped pulpal floor in the second maxillary molar, the entrance of MB2 is located very close to the palatal orifice, a common finding in these kinds of teeth

It should be taken into consideration that literature data from laboratory studies on the prevalence of the MB2 canals are subject to strong variations due to differences in the experimental design. Thoroughly studying the description of the methods used in these publications is an absolute requirement if someone wants to rely on the found percentages of MB2 canals. Properly designed histological and micro-CT studies could be seen as a gold standard when examining the prevalence of the MB2 canal in extracted teeth. Considering such studies, a prevalence of more than 90 % MB2 canals in the first and more than 55 % MB2 canals in the second maxillary molars should be accepted as clinical reality. Figure 1.6 shows the clinical negotiation of MB2 in a retreatment case with corresponding CBCT imaging.

This division of the mesiobuccal root canal can take place at different levels and initiate various configurations. Again, it is the result of the apposition of secondary dentin after the formation of the mesiobuccal root. After root formation, the cross section of the mesiobuccal canal resembles a kidney shape with a larger buccal and a smaller palatal part. This explains the smaller diameter of the MB2 canal after the deposition of secondary dentin [20]. Neaverth and coworkers found the prevalence of a second mesiobuccal canal in under 20-year-olds significantly lower than in an age group of 20–40-year-old patients [21].

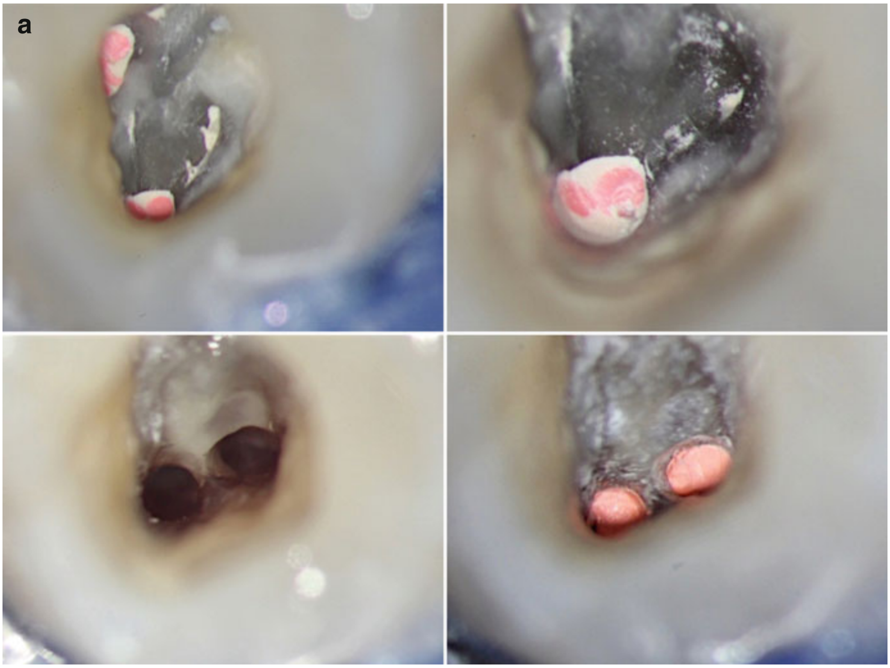


Fig. 1.6 (**a**) Clinical image during endodontic retreatment of a first maxillary molar with untreated MB2. The location identification of MB2, the access, preparation, and also filling of the canal system after retreatment of MB1 is shown. (**b**) Corresponding CBCT scan prior to retreatment of the first maxillary molar is shown in (**a**). Note the unprepared and unfilled MB2 depicted in different slices of the original dataset (*arrows*)

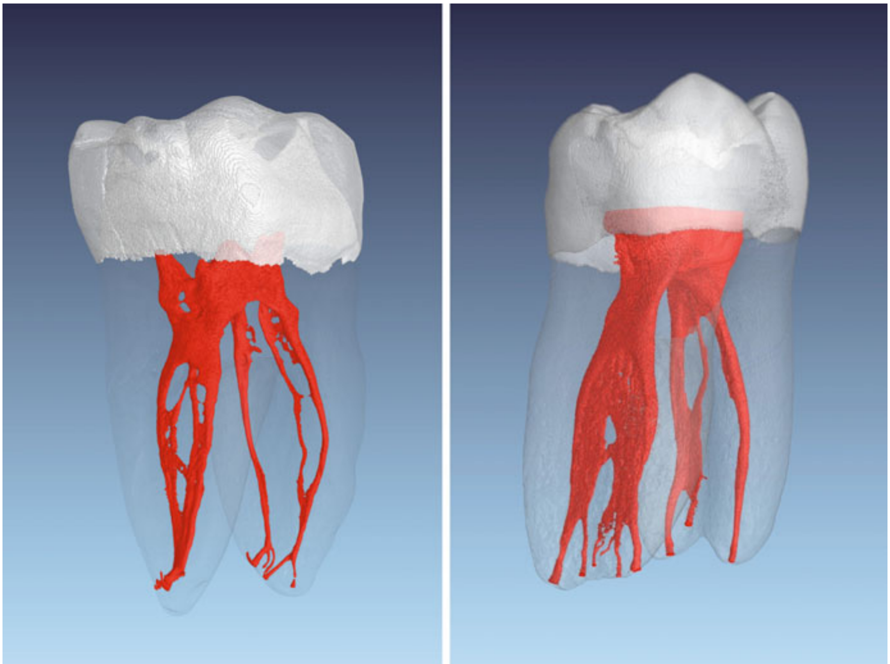


Fig. 1.11 Micro-computed tomography images of two extracted first mandibular molars with complex distal root canal anatomy. Note the various intercanal communications and the severe curvature to the distal aspect in the apical portion (*left*) and six portals of exits (*right*)

mesiobuccal, mesiolingual, and the distobuccal canal exhibited a more oval canal shape, whereas the distolingual canal revealed a relatively round canal shape [35]. The occurrence of an additional mesiobuccal root is called radix paramolaris. The frequency of a radix paramolaris is described with less than 0.5 % [33].

1.5.2 Additional Root Canals

Three canals were reported in about 61 %, four canals in 36 %, and more than five canals only in approximately 1 % [33]. In a systematic review [36] as well as reported earlier by Vertucci [7], the type IV configuration is the most frequently encountered canal configuration in the mesial root of first mandibular molars followed by type II. However, newer data generated by micro-CT showed even more complicated canal anatomy in mesial roots of mandibular first molars [28]. In about 9 % of the studied teeth, even four canals were observed in some root sections of the mesial root.

In the distal root of mandibular first molars, type I configuration dominated (63 %), followed by types II (15 %) and IV (12 %) [36]; again micro-CT studies showed a more complex image [30] (Fig. 1.11).

superimposition of the mental foramen over the apex of lower mandibular teeth and the relationship of the inferior alveolar canal to the apices of molar teeth.

Having identified the need for endodontic treatment based on both the pulpal and periradicular diagnoses, the radiographic information gathered will facilitate the treatment procedure. One of the greatest causes of failure of molar endodontics is failure of the clinician to locate and treat all parts of the canal system [63]. The appropriate radiographic imaging techniques (periapicals and/or CBCTs) will provide the clinician with the information to address these shortcomings (Figs. 2.6 and 2.7). CBCTs are especially helpful in this respect (Figs. 2.6, 2.7, and 2.8).

It is important for the clinician to recognize abnormal structures or changes on a radiograph and arrange for these variations to be investigated. A list of these radiographic impressions is listed here:

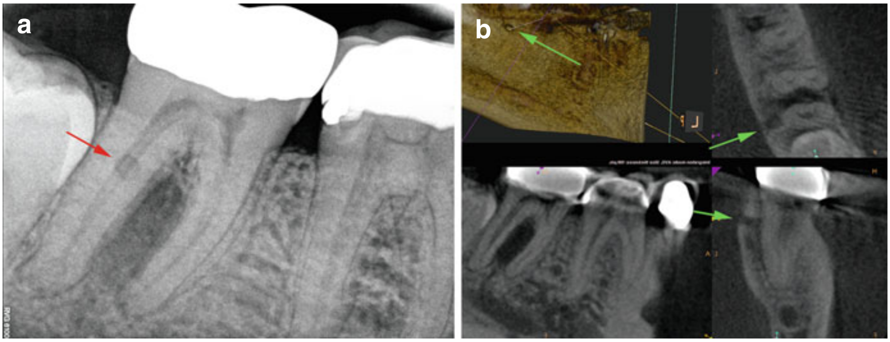


Fig. 2.7 (**a**) Periradicular radiograph of a mandibular second molar tooth showing a radiolucency overlaying the distal canal; (*red arrow*) (possibly external root resorption). (**b**) CBCT of the same tooth showing that that region of radiolucency is a defect in the lingual cortical plate of the mandible; (*green arrows*)

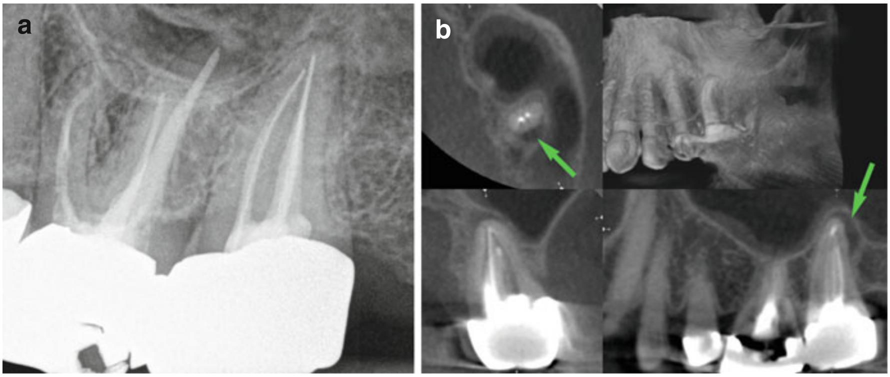


Fig. 2.8 (**a**) Periradicular radiograph of a maxillary second molar tooth. (**b**) CBCT of the same tooth clearly showing a region of radiolucency at the distal apical aspect of the tooth; (*green arrows*)

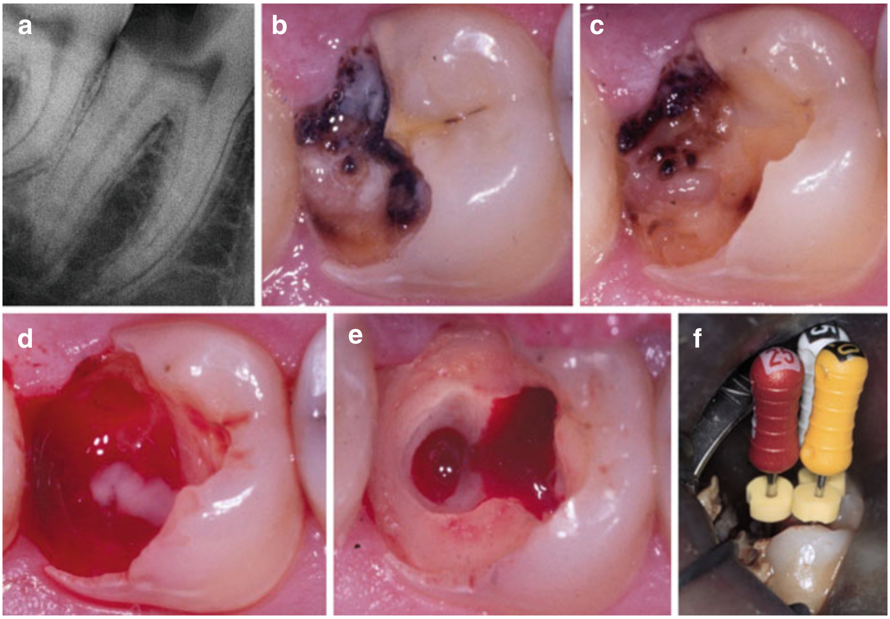


Fig. 4.2 (**a**) Preoperative periapical radiograph showing extremely deep caries lesion in the mandibular second molar with apical periodontitis. (**b**) Tooth shown before treatment. Clinically the tooth is vital and the combined diagnosis is "irreversible pulpitis" and apical periodontitis. (**c**) Following excavation an exposure of the pulp is present with pus. (**d**) During further access to the pulp cavity focal areas of pus are noted within the bleeding inflamed pulp. (**e**) Complete excavation performed before placement of "endodontic working" restoration and preparation of an aseptic working field. (**f**) Root canal treatment is initiated and determination of working length is about to be accomplished

4.4 Indications and Treatment Concepts for Vital Pulp Therapy

The principal indications for performing vital pulp therapy are carious lesions, mechanical iatrogenic injury, and trauma. In the context of molar endodontics, the most frequent cause for endodontic treatment including vital pulp therapy has, in the general practice environment, been caries [30]. Therefore, the aligned treatment guidelines are described within the "scenario" of a carious pulp exposure. From the literature, it is often unclear whether the clinicians are creating a pulp exposure by accident or whether it is the intention to do a pulp exposure; moreover the depth of the carious pulp exposures are seldom defined in clinical studies [31]. The following vital pulp therapy guidelines will include these aspects.

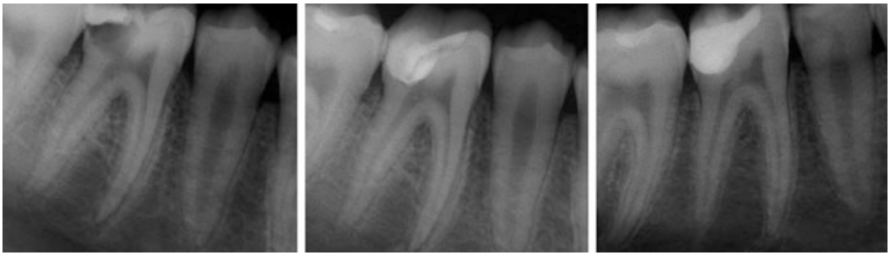


Fig. 4.4 (*Left*) Preoperative radiograph of a 12-year-old child showing first mandibular molar with extremely deep caries. (*Middle*) After excavation and carious exposure and MTA application. (*Right*): Postoperative 1-year follow-up. Tooth vitality present and well-defined *lamina dura* in the apical region. Note the formation of tertiary dentin (Courtesy of Dr. G. Bogen)

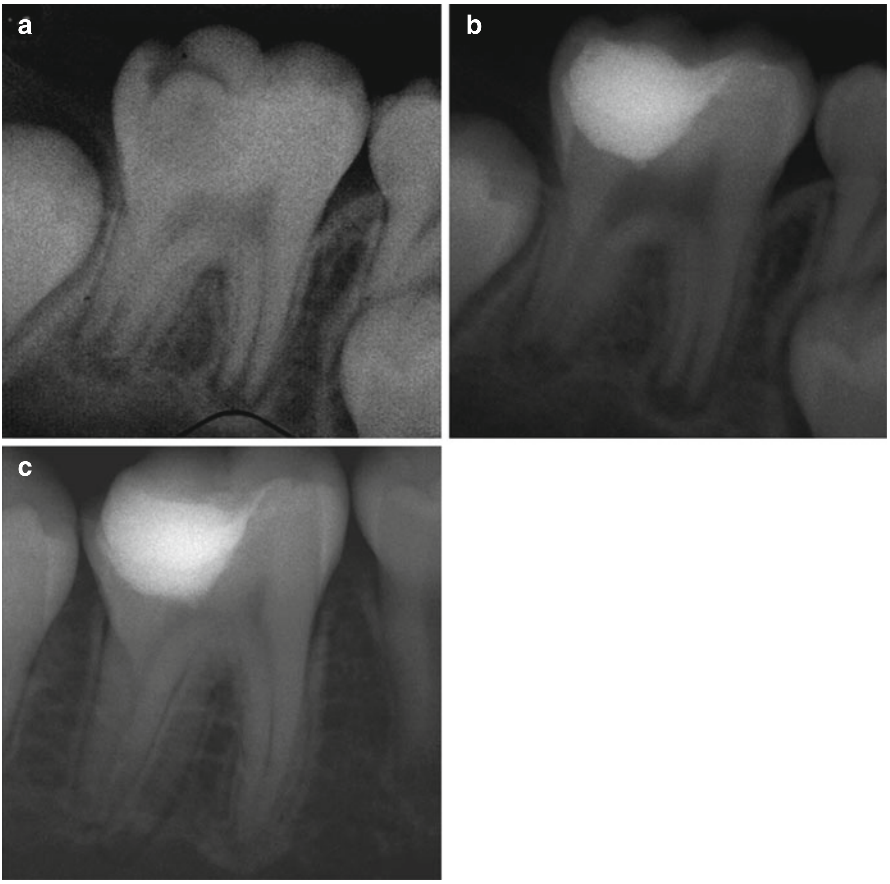


Fig. 4.5 (**a**) Preoperative radiograph of a 7-year old child, showing first mandibular molar with deep caries. (**b**) After excavation and carious exposure and MTA application. (**c**) Postoperative 3-year follow-up. Tooth vitality present and completed root formation (Courtesy of Dr. G. Bogen)

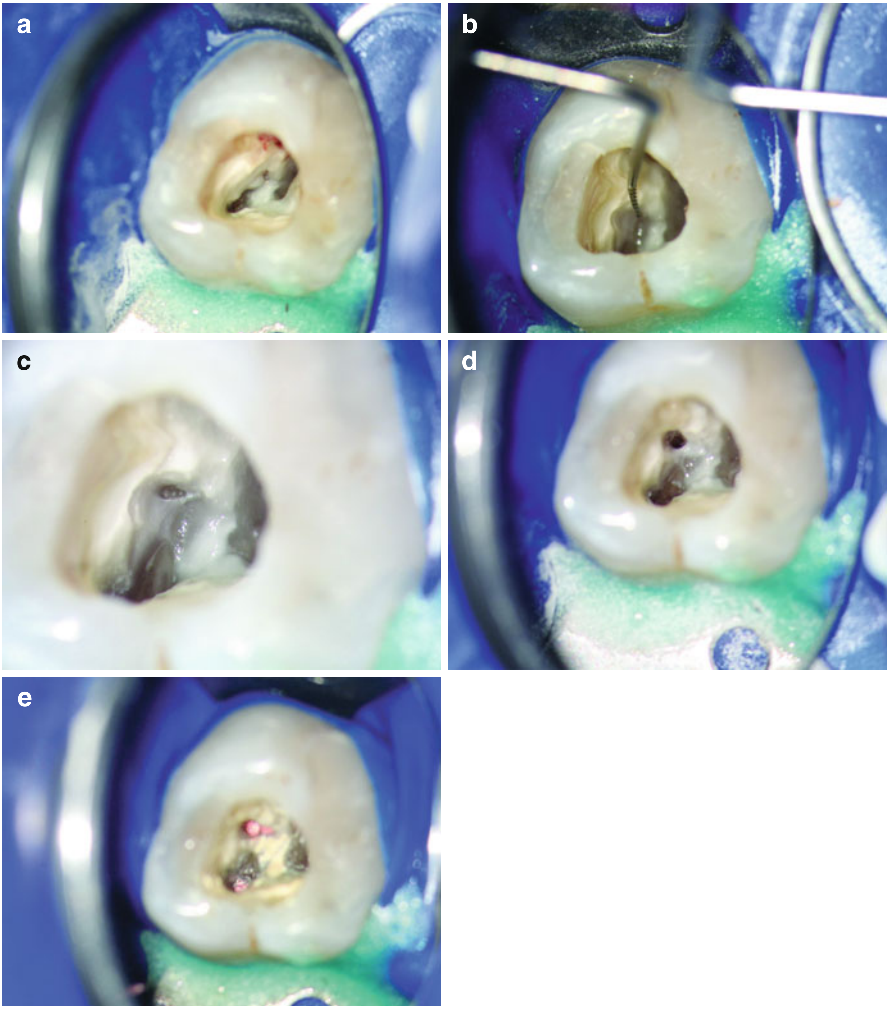


Fig. 5.2 Identification and instrumentation of a calcified MB2 of a first maxillary molar. Access cavity overview with dentin obstructing the canal entrance to MB2 (10× magnification). (**b**) Canal identification after ultrasonic dentin removal (10×). (**c**) Initial preparation of MB2 for straight-line access (16×). (**d**) Completely instrumented MB2 canal prior to root filling (10×). (**e**) Root fillings in mesiobuccal canals (10×) (Images **a**, **b**, and **d** from Setzer and Kim [38]; with permission)

relation to the mesiobuccal and mesiolingual cusp tips. The distal canal(s) will be found distally to the furcation, respectively distal to the buccal developmental groove. Due to the curvature of the distal root, it is mostly sufficient to limit the access cavity extension in distal direction. Straight-line access will still be possible. If only one distal canal is present, it is located centrally in buccolingual direction. It commonly has a long oval canal cross-section stretching buccolingually.

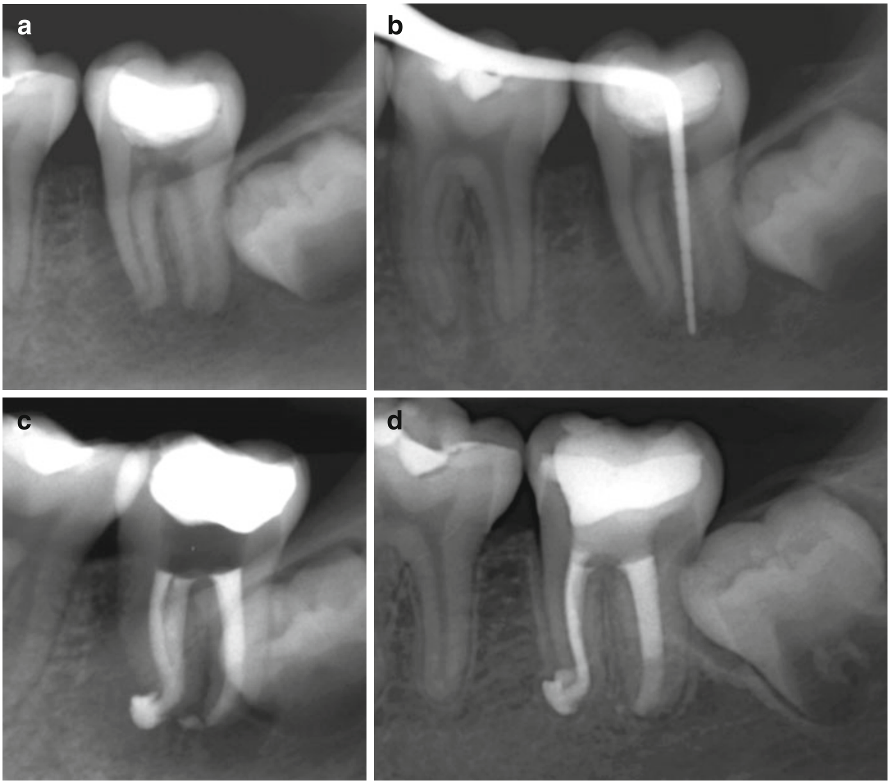


Fig. 6.11 Clinical treatment of a mandibular second molar with pulp necrosis and a large apical canal size (**a**). The periodontal probe was placed in a deep periodontal pocket (**b**). The final radiograph (**c**) and a 2-year follow-up (**d**) show placement of a MTA barrier in the distal canal and evidence of osseous healing

Adapting the master cone to fit correctly at the apical end of the preparation often means that the tip needs to be cut back to increase the diameter. A more precise way to modify the cone is to insert it into a gutta-percha gauge (Fig. 6.12) and to cut the cone to the same tip size as the last file that was taken to working length.

If the cone looks buckled or crimped, the taper of the preparation may have been insufficient and tug-back was experienced in the middle third of the root canal instead of at the most apical level.

6.4.3 Step 3: Canal Drying and Sealer Application

At this point in the clinical procedure, the root canal system should be dried, first by removing excess fluid with a suction cannula and a series of paper points that are placed to WL. Molar canals have often multiple communications and so all canals must be dried completely before any one canal may be filled. There is no clinical evidence to suggest the use of alcohol or any other solution at this stage.

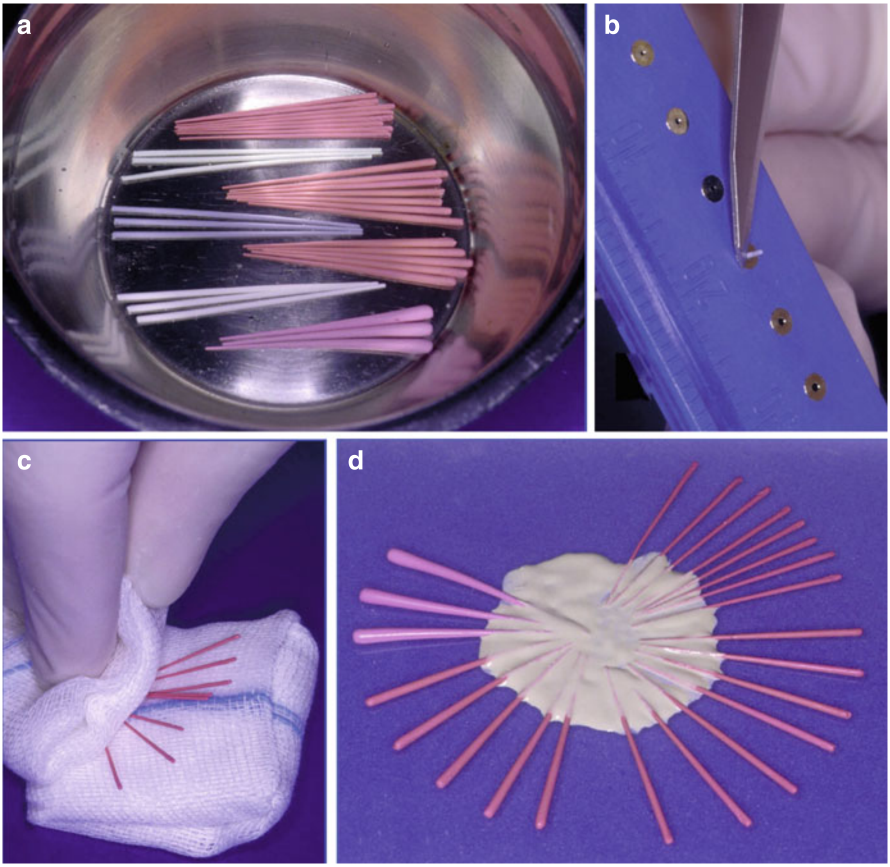


Fig. 6.12 In preparation for obturation, gutta-percha cones are disinfected by immersion in NaOCl (**a**), cut to the needed tip size (**b**), and dried with gauze (**c**). Prior to the obturation, cones can be dipped in the sealer (**d**)

The appropriate amount of sealer is then deposited into the canal system. This may be done using a lentulo spiral, a K-file, or the master cones themselves; either method is acceptable, provided that an appropriate amount of sealer is deposited (Fig. 6.13). If the master cones are the primary carrier for sealer, they should be once removed and inspected for a complete coating with sealer.

6.4.4 Step 4: Filling the Apical Portion (Lateral or Vertical Compaction)

The master cones are placed close to WL using a slight pumping motion to allow trapped air and the excess sealer to flow in a coronal direction. The marking on the cone should be close to the coronal reference point for WL determination.

For lateral compaction, a preselected finger spreader is then slowly inserted alongside the master cone to the marked length and held with measured apical

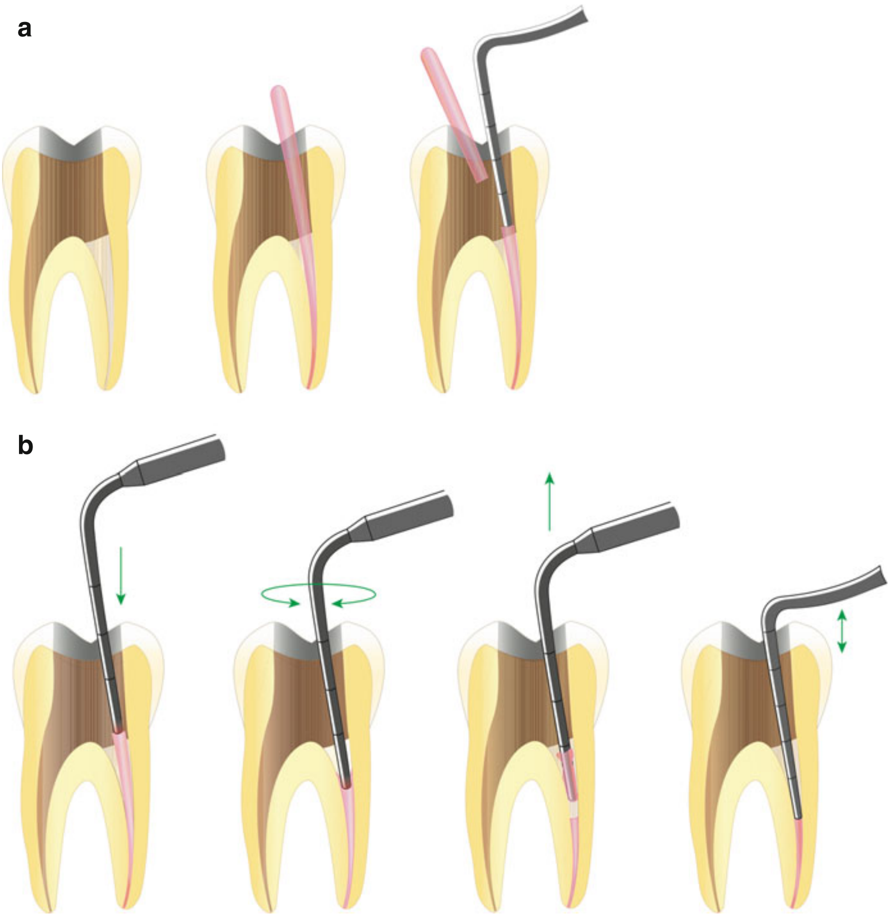


Fig. 6.15 For vertical compaction, the main cone coated with sealer is placed to working length and excess removed at the orifice level (**a**). The next sequence compacts the warmed gutta-percha mass and removed more excess, completely filling the apical canal segment (**b**). The coronal canal portion may be filled with various methods, most often with plastified gutta-percha from an extruder (not shown) (Reprinted from Arens et al., 2009, with permission)

3. Apical gutta-percha mass was not compacted to a flat contact surface.
4. Insufficient sealer was placed to the contact surface.

For both lateral and vertical compaction, the gutta-percha mass in each canal should end about 1 mm below the pulpal floor, leaving a small dimple. Only in cases where placement of a post is planned (see Chap. 7), gutta-percha is confined to the apical 5 mm. All molar canals that do not receive a post should be covered with an orifice barrier (Fig. 6.16) to protect from leakage prior to placement of a definitive restoration [74], promoting healing of apical periodontitis [75]. Materials that are suitable for such a barrier include light-curing glass ionomer, flowable composite, or fissure sealant. Placement of these materials requires a clean and bondable

Fig. 7.7 Replacing an inadequate metal crown by a ceramic endocrown on tooth 46 (#30) (Courtesy of Dr. B. Lambert)

invasive preparation of tooth structures and lower risk of root damage, and second, the more favorable ratio between crown height and width in molars, which leads to smaller forces exerted on restorations compared to incisors for example, with a much larger restoration-tooth interface. Of course, any flaw within the material can increase the risk of restoration fracture, and any procedural mistake during the bonding procedure can favor debonding. Moreover, the reduction of bond strength with time under load and temperature changes, which is material specific, needs to be kept in mind [70]. In fracture strength experiments, ceramic endocrowns were shown to be more resistant to compressive forces than teeth restored with fiber posts, composite core, and conventional full crowns. In both cases, failure occurred by fracture of the tooth in most cases [71]. Again, fracture strength values were higher than physiological forces and the compression load was applied with a 45° load direction, which may not correspond to most situations in the molar region, where most forces are probably axial.

These promising in vitro results are confirmed by clinical studies. One study investigated CAD/CAM ceramic crowns placed in posterior teeth ranked in three different groups with various stump height (bondable and retentive surface) with one group of 70 molars that had only a pulp chamber retention cavity [72]. Among the molars, no significant difference in survival was observed between the three groups, with a survival of up to 94 % after a mean service life of 55 ± 15 months. As mentioned by the authors, comparable survival rates have been previously documented for conventional metal-ceramic or all-ceramic crowns. Of the 70 molar endocrowns,

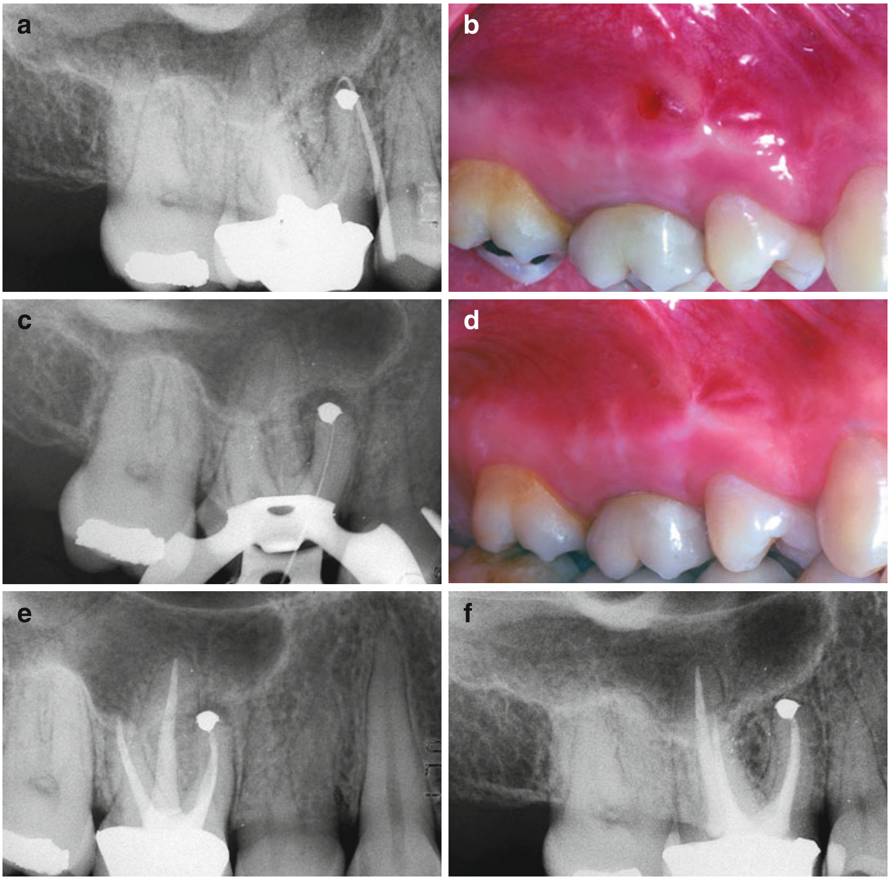
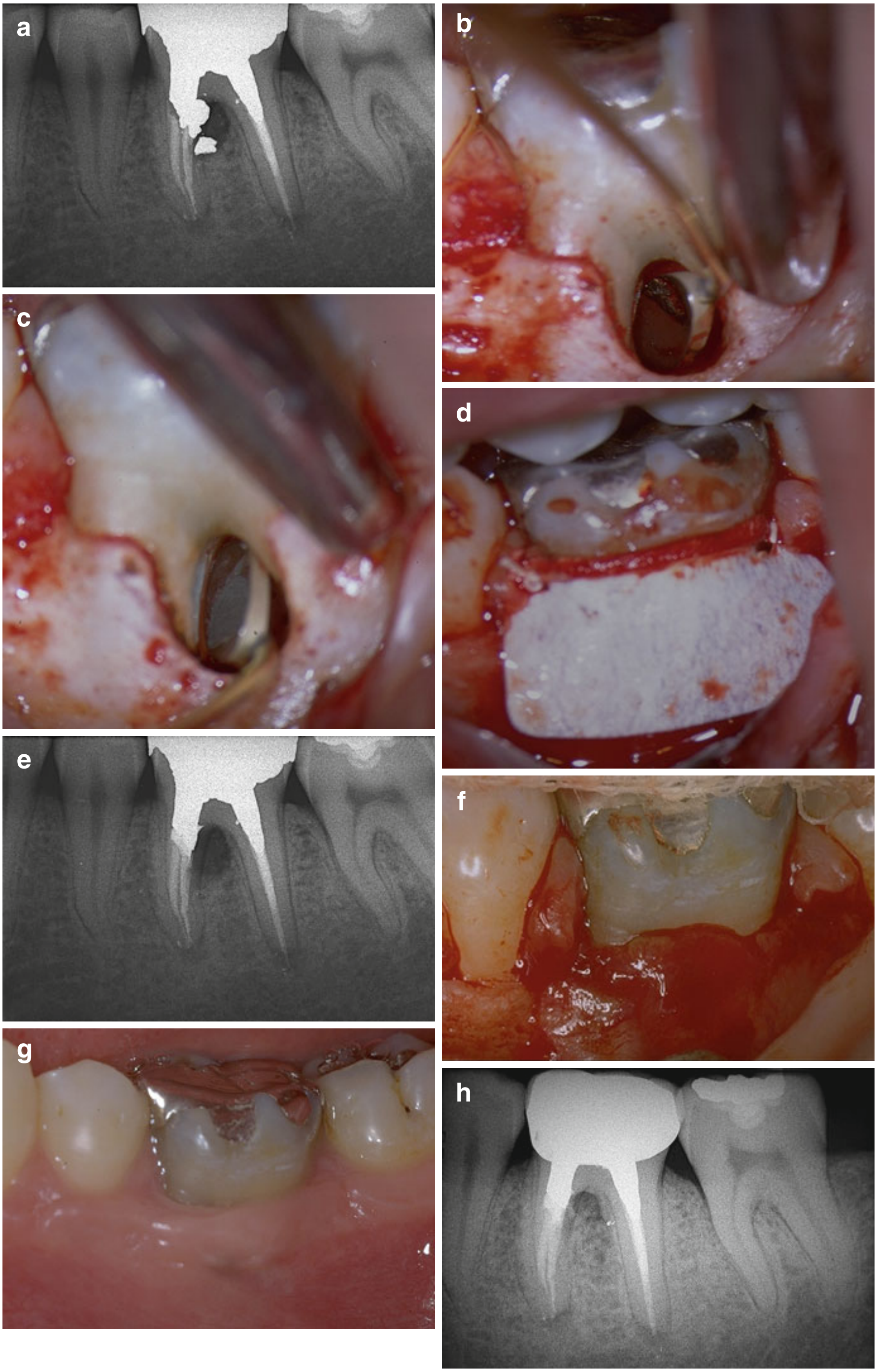


Fig. 9.2 (**a**) Preoperative film of the maxillary right first molar. The apical surgery has been performed on contaminated and empty root canals. The surgical failure must be retreated nonsurgically. The gutta-percha cone traces the sinus tract. (**b**) A sinus tract is evident clinically. (**c**) Working length radiograph of MB1. (**d**) After cleaning and shaping four canals, the sinus tract disappeared. (**e**) Postoperative film. (**f**) Two-year recall

9.2.1 The Rationale for Retreatment

The clinical practice of root canal treatment has changed markedly over the last 20 years. The introduction of rotary instrumentation, of various new obturation systems, of ultrasonically powered devices, and of magnification systems (in particular operating microscopes) has significantly increased the success rate of primary endodontic treatment and endodontic surgery [3, 4].

Perhaps, the most important difference today is that an endodontist's manual dexterity is no longer the prime determinant for success. Obviously, individual skill always makes a difference, but with the use of modern endodontic techniques,


a
b
c
d
e
f
g
h

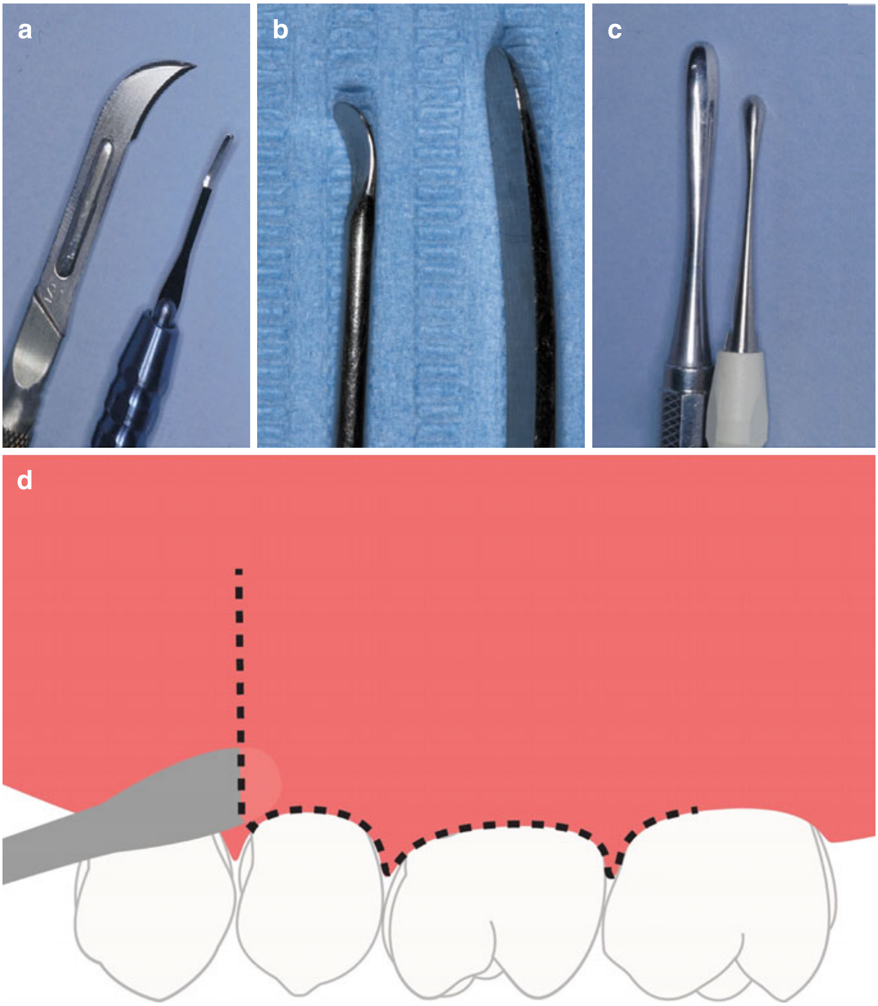


Fig. 10.3 (**a**) Incisions may be made perpendicularly to bone with a conventional scalpel. Alternatively, a microscalpel (**b**) may be used when making the incision under the microscope. (**c**) Prichard or Molt curettes are appropriate to initiate flap elevation. (**d**) Elevation may be started by inserting the elevator at the junction of the vertical and horizontal incisions; vertical force is then applied with a slow, firm, and controlled peeling motion, following closely the cortical bone contour, in order to release the flap to a level completely revealing the extent of the osseous lesion

10.4.5 Osteotomy Window (Low-Power Magnification)

An osteotomy window approximately 5 mm diameter has to be made in order to allow easy access for instruments and devices to the apex. A round tungsten bur or a 5 mm trephine may be used to create the "access cavity" at the hard tissue level, to the involved molar apices.

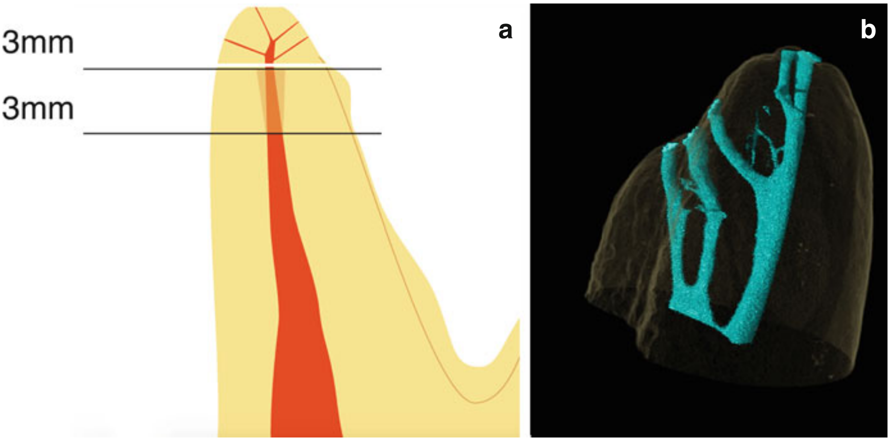


Fig. 10.7 (**a**) "Rule of threes": The goal is to remove the apical 3 mm of each involved root by the apicoectomy and another 3 mm of the canal is instrumented and sealed by the retrofill. The final 6 mm of the canal is treated to eliminate or block most frequent communications at the apical third area between main canal and the periodontium. (**b**) Micro-computed tomography rendering of the mesio-buccal apex of a maxillary molar with multiple apical ramifications, indicating the complex anatomy that may be present in the apical portion of any molar root (Image B courtesy of Dr. O. Peters)

Fig. 10.8 Staining the resected apex with methylene blue dye discloses the presence of connective tissue and can serve to demonstrate that the cut of the root has been complete (360° continuously stained outline) or incomplete (broken outline). This staining step is also important to detect otherwise undiscovered canals, isthmuses, apical fractures, and craze lines

molars, in electron microscopic studies, and micro-computed tomography data (see also Chap. 1 in this book). Preferably there should be a 0° bevel and a fluted carbide or Lindemann bur should be used with an Impact Air handpiece, under copious irrigation. Current microinstruments like micromirrors, small ultrasonic tips, and micropluggers permit to work with such a small bevel. After resecting the apical root segment, methylene blue dye is used to ensure the resection is complete and for canals and isthmus inspection (Fig. 10.8).

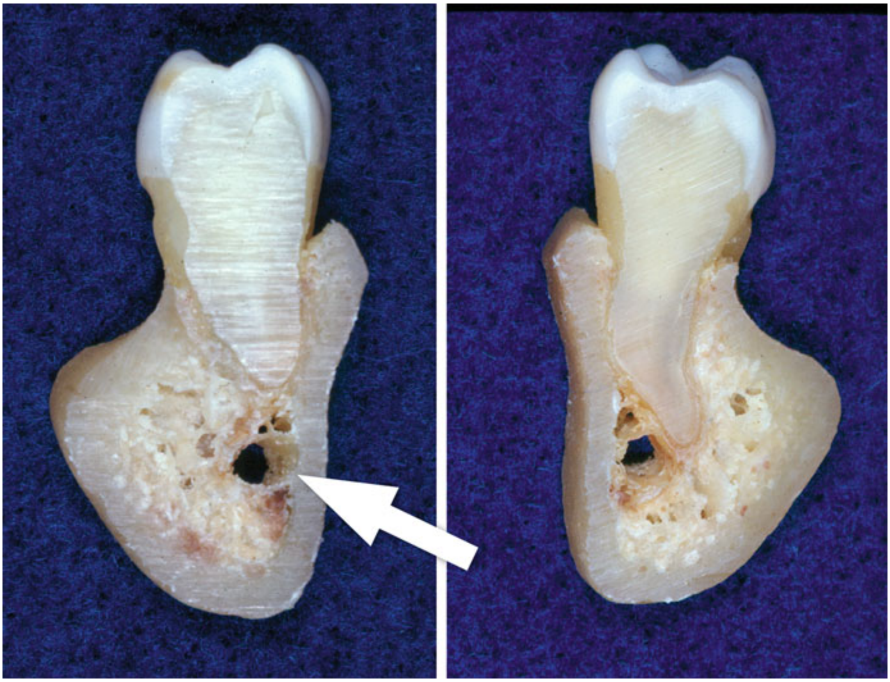


Fig. 10.18 (*Left* and *right*) The external oblique ridge complicates the surgical access to the apex of second and third molars. In many cases, the distance is too large for a buccal approach. Also structures such as the inferior alveolar never are close to the lingual cortical bone as shown in this specimen (Image courtesy of Dr. J. Gutmann)

10.6.3 Clinical Case Selection

Apart from the technique procedure itself, case selection is the most important factor in replantation prognosis. A clinical case is shown in Fig. 10.19; here the inability to debride and prepare via an orthograde approach necessitated the surgery and the access was too close to the mandibular canal.

10.6.4 Technique

Replantation is biologically based on the viability of the cells and fibers of the periodontal ligament after it's stay outside of the socket. It was previously believed that a tooth that was outside of the alveolar socket will suffer from resorption or ankylosis upon replantation but current data overwhelmingly show that this depends on the viability of the cells of the periodontal ligament: the longer the root is outside of the socket, the more readily resorption and ankylosis will occur [31–34]. This is the reason that, before the extraction, the clinical team must rehearse all the surgical steps, so that once the tooth has been removed, the procedure can be carried out efficiently and in minimum time [30].